N66 32948

CAPILLARY SCREEN PUMP IN A FORCED CONVECTION SYSTEM

Thomas O. Thostesen

Jet Propulsion Laboratory

Concentrated internal power dissipations in large, densely packed spacecraft may require means of transferring heat in excess of the radiation and structural conduction paths arising from the packaging design. Either additional conduction paths or convection loops would then be necessary.

The present investigation is directed toward meeting the convective loop needs within the present restrictions of weight and power. The purpose is to evolve a two-phase heat transfer device which does not require mechanical or electrical power and will operate reliably for a period of years while withstanding the vibrations and accelerations of the spacecraft environment. The thermal energy would be transferred by evaporation of a fluid at the heat source and condensation of the vapor at the heat sink. The fluid would be transported by differences in vapor pressure and surface tension forces.

Figure 1 shows such a system employing a wick. The liquid is evaporated at the warm end of the wick, the vapor transfers to the cold end and condenses, and capillary forces replenish the liquid supply in the evaporator. Wicks are not necessarily the optimal system. Viscous losses, proportional to $\frac{v}{r^2}$, are quite large in miniscule passages. Since the capillary force is inversely proportional to r, the velocity in the tube is proportional to the hydraulic radius in case the system is not heat transfer limited. In this simplified case the system should have passages as large as are consistent with the vibrational environment.

One method of reducing the viscous forces is to eliminate the wicking in the piping which joins the condenser and the evaporator. The next area to investigate is the wicking in the evaporator and condenser. The phase change occurs just at the surface of the wicking (or at the meniscii - Fig. 2). An analysis of the heat transfer shows that most of the heat of vaporization is in the immediate vicinity of the meniscus. This would suggest that the ideal system would provide just the meniscii and eliminate the constrictions present in wicks.

The proposed system is shown in Figure 3. Here the fluid is retained and moved by the surface forces generated in the meniscii formed by a screen mesh. Evaporation and condensation occur at the surface of the liquid, with the heat flowing between the surface and the source or sink. Figure 4 shows in more detail the mechanism of the screen meniscii. The pressure differential across a meniscus is inversely proportional to the radius of curvature. In a capillary, this differential is constant as the meniscus changes position (4.a.) In the screen system, the radius of curvature changes as the meniscus moves (4.b. and 4.c.). Therefore, the pressure differential is a function of the amount of liquid in the system at that point. As the meniscus recedes, more "suck" is applied to the liquid. 4.d. illustrates that woven screening is not as simple a situation as parallel rods or a toroid.

Preliminary tests with water as the fluid were run at one atmosphere to determine approximate capabilities. The screen unit used a 4" diameter 150 mesh (wires per inch) stainless steel screen separated from the source or sink plate by 1/32". It was found that this unit would:

a) Support a head of 4" of water in suction.

b) Evaporate water at the thermal rate of 20 watts at 156°F against zero head.

c) Condense water at the thermal rate of 75 watts with the condensate being drawn off by a pressure differential of 2" of water.

d) Withstand 40g rms vibrations from 100 to 2000 cps.

A test with the vapor space evacuated of noncondensable gas showed that this causes the vapor flow to be maximized.

Based upon the preliminary data, a design goal for a closed cycle, evacuated unit was established as 20 watts for 6 hours with a temperature differential between source and sink of 50°F over a distance of 1 foot with evaporator and condenser diameters of 4". These goals are being approached by investigating the evaporator and the condenser separately. When the two components perform satisfactorily, they will be combined into a closed system.

Tests on the evaporator to date have not been too encouraging, but hopes are high. Early experiments were plagued with bubbles forming in the supply line from the reservoir to the evaporator, choking off the flow. This was eliminated by replacing Tygon lines with glass tubing and surgical rubber tubing. The maximum evaporation rate in a vacuum has been 3 watts, with the limitation imposed by catastrophic evaporation behind the screen in the liquid space. It is expected that this is a dissolved gas problem and better deaeration techniques will be the answer.

The condenser side of the system has not yet been tested in a

vacuum environment but should not be a problem, since there is much less probability for bubble formation.

As noted, bubble formation in the liquid phase is a serious problem. A bubble which has sufficient volume to contact the inner circumference of a tube blocks that tube against passage of liquid by capillary forces. A bubble behind a screen blocks off part of the screen. Once the bubble forms, it easily grows, fed by vapor from evaporation. Care in deaeration and material selection have and will reduce this problem greatly. In addition, bubbles behind the screen have disappeared, probably due to rupturing of a meniscus in the screen so that local capillary forces could expel the vapor through the opening.

The launch of a spacecraft might be violent enough to cause the liquid and vapor phases to become intermixed, requiring that the system be charged following launch. However, preliminary tests have shown the system to be quite resistant so that the unit might be charged before launch.

BIBLIOGRAPHY

1. T. O. Thostesen, "Capillary Pump in a Forced Convection System," JPL SPS No. 37-17, Vol. IV, pp 145-147, October 30, 1962.

2. T. O. Thostesen, "Screen Capillary Pump in a Forced Convection System," JPL SPS 37-20, Vol. IV, p. 38, April 30, 1963.

3. T. O. Thostesen, "Screen Capillary Pump in a Forced Convection System," JPL SPS No. 37-23, Vol. IV, p. 58, October 31, 1963.

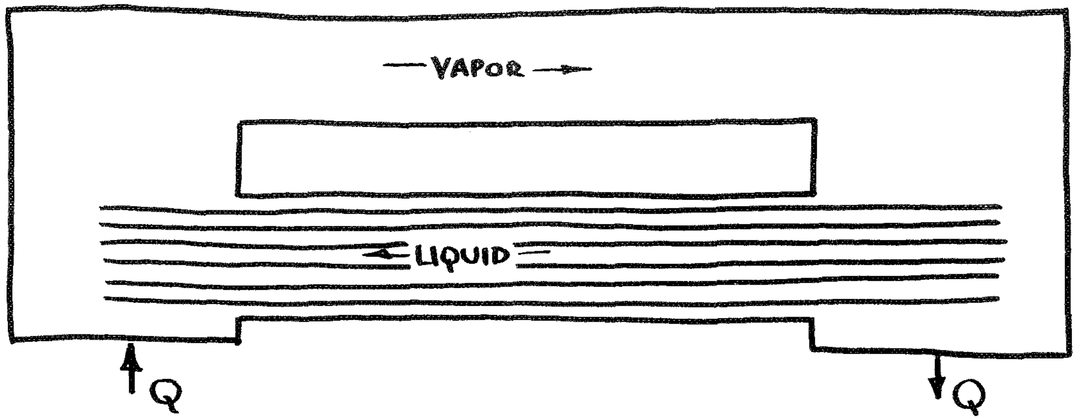

Figure 1

Capillary Wick Pump

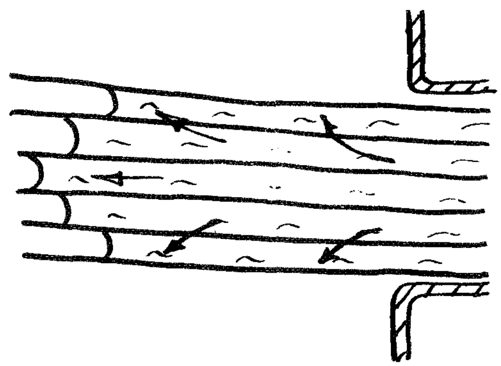

Figure 2

Flow in the End of a Wick

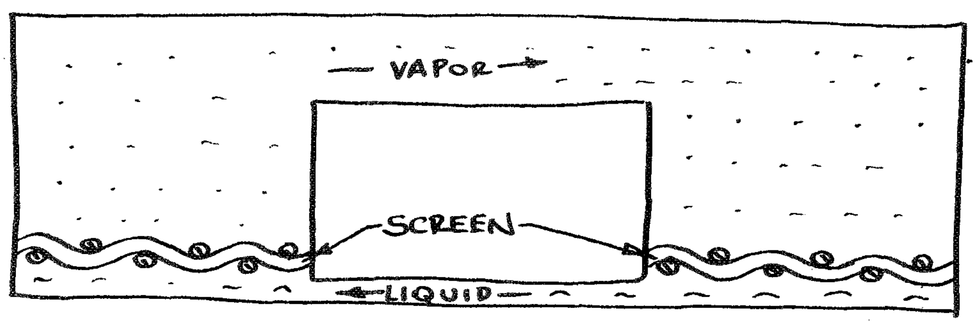

Figure 3

Capillary Screen Pump

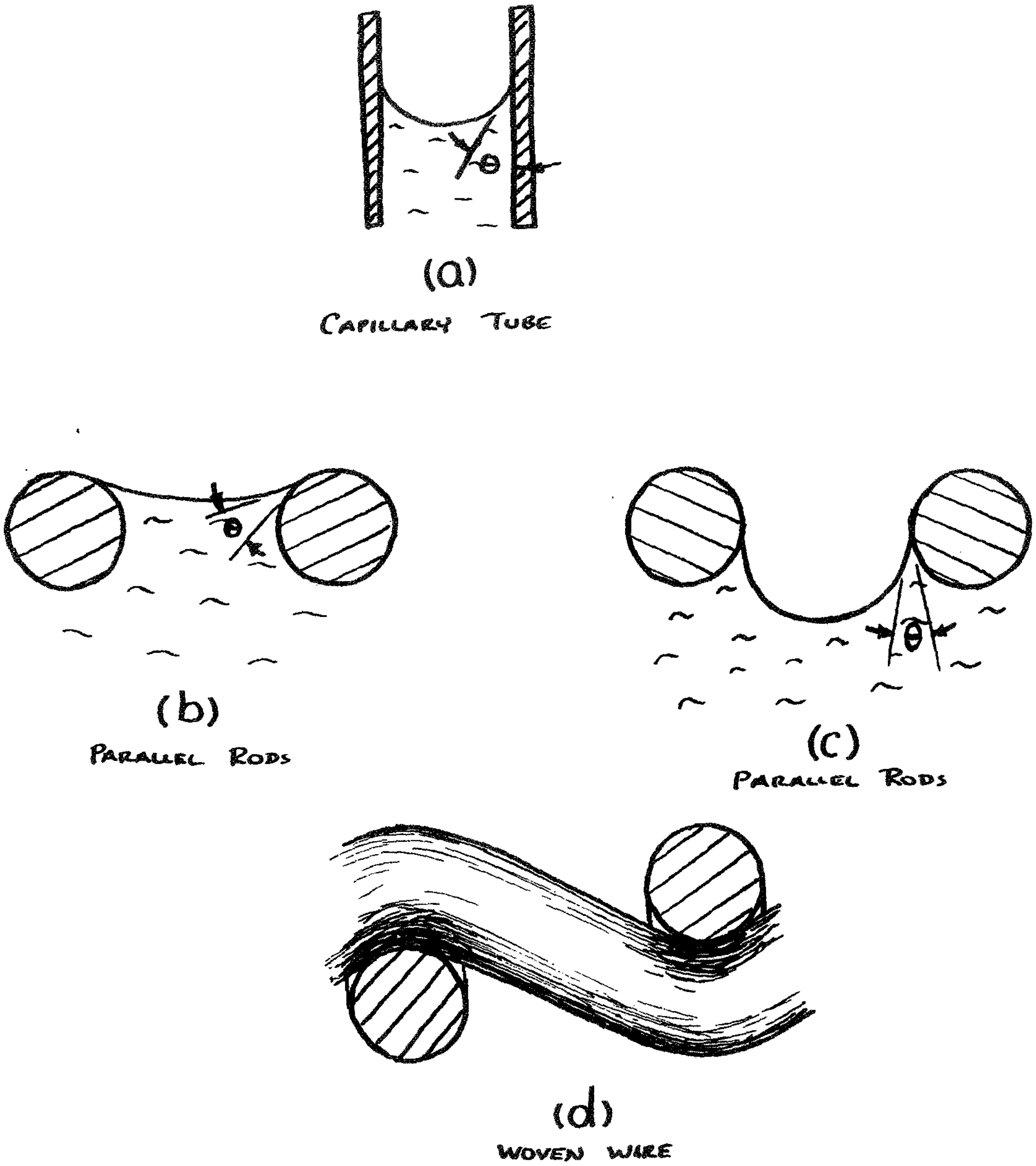

FIGURE 4

MENISCUS SHAPES